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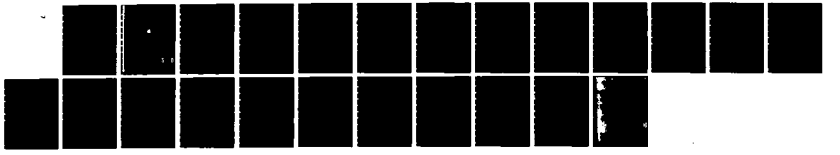

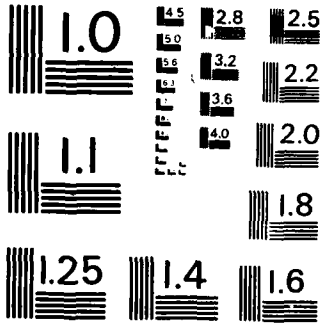

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Woods Hole Oceanographic Institution

Undersea Acoustic Research

by

Robert C. Spindel
Principal Investigator

January 1984

Technical Report

Prepared for the Office of Naval Research

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UNDERSEA ACOUSTIC RESEARCH

by

Robert C. Spindel, Principal Investigator

Woods Hole Oceanographic Institution

Woods Hole, Massachusetts 02543

January 1984

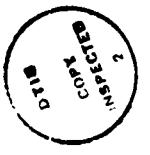
TECHNICAL REPORT

ABSTRACT

This is the final report of Contract N00014-77-C-0196 between the Woods Hole Oceanographic Institution and the Office of Naval Research for the contract period 1 January 1977 to 28 February 1983. This contract supported a broad program of research and development in underwater acoustics related to present and future Navy systems and requirements.

The bulk of this contract research was conducted from 1977 to 1981, during which time the categories outlined below were all areas of active research. (Between 1981 and 1983 the contract remained in effect, although only in the area of bottom acoustics and at a reduced level.) The primary contract products are the published technical reports and papers listed below. These reports give detailed descriptions of the research work and the specialized techniques, methods, and instrumentation developed to support this research program.

The final report contains a brief review of the program highlights and a bibliography of associated reports.



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INTRODUCTION

This is a final report of the research and development activities conducted at the Woods Hole Oceanographic Institution under the auspices of the Office of Naval Research Contract N00014-77-C-0196, during the period 1 January 1977 to 28 February 1983.

There has been a continuous series of underwater acoustics research programs at Woods Hole since the founding of ONR. The immediate predecessor to the present contract was Contract N00014-70-C-0205; NR 083-25 which ran from 1967 to 1976. The successor to this contract is Contract N00014-76-C-0152. It is presently in effect. Each change of contract has included transfer of equipment, reports and contractual obligations. Most changes have also included the initiating of new research programs.

The major objective of this series of contracts has been to devise analytic and experimental methods to enhance the application of acoustics to Navy missions and systems. The general direction of the work has been guided by perceived Navy needs. During the present five year contract period, we have worked on a wide variety of problems including:

(1) the fluctuations in low frequency acoustic signals that are transmitted long distances underwater due to multipath and internal oceanic processes;

(2) the acoustic remote sensing of near surface phenomena such as mixing processes and internal waves, as well as the distribution of natural and man-made suspended particles;

(3) the development of in situ, microprocessor controlled sources and receivers for long term data collection;

(4) the development of the technique of acoustic ocean tomography for remote sensing of the sound speed field in an ocean volume;

(5) the detection and estimation problems associated with passive acoustic arrays and the localization and tracking of both narrowband and wideband sources;

(6) the development of a variety of theoretical and empirical techniques aimed at measuring the complete, complex acoustic reflection coefficient of the ocean bottom.

In addition to these areas of research and development, we have frequently served in an advisory capacity to a variety of Navy activities. These have included representation on Navy panels and committees concerned with oceanographic and acoustic problems such as towed array systems, mine search and defense, ambient noise, signal coherence, and seismic signal detection. Discussions with FNOC, NRL, NOSC, NUSC, NORDA, NAVOCEANO, SACLANT, COMOCEANSYSLANT, NADC, NAVSEA, various project management offices, and others have occurred on a continuing basis.

The following paragraphs are brief summaries of the major areas of focus under this contract. Pertinent reports and other published material are listed for each area.

PROGRAM SUMMARIES

I. Acoustic Fluctuations

The basic issues addressed here involved the causes and magnitude of the variations and fluctuations observed in low frequency ($<$ 500 Hz) acoustic signals transmitted to long ranges (100 to 1000's of km). Remote, in situ, moored acoustic sources and receivers and an acoustic navigation technique

based on Doppler shifts and phase measurements were developed to conduct a series of at sea field exercises. Relationships between acoustic fluctuations and multipath interference and internal wave dynamics were established.

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II. High Frequency Remote Sensing of the Near Surface Ocean

This program employed high frequency acoustic echo sounding techniques to investigate near surface ocean mixing processes, internal wave dynamics, and the distribution of natural and man-made particulate matter. A series of field experiments was conducted with a specially designed sonar capable of yielding high resolution records over a wide range of frequencies (20 KHz to 5 MHz). Evidence of internal wave formation, of breaking, sewage plumes and other phenomena were obtained.

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III. Ocean Acoustic Tomography - Mapping of the Ocean Sound Speed Field

This portion of the program is an outgrowth of (I) above. Whereas in (I), we sought to establish the relationships between acoustic fluctuations and oceanic processes, here we exploit knowledge of the relationships to solve the inverse problem, i.e., we measure acoustic fluctuations and infer the underlying oceanic processes. Specifically, we measure the variation in acoustic travel time of pulses transmitted through the ocean volume to measure changes in the ocean's sound speed field. Sound speed is a function of temperature, salinity, and to a lesser extent, other dissolved chemical agents.

A suite of moored equipment was developed especially for this application. Acoustic sources and receivers, outgrowths of those developed in (I), transmitted and received phase coded pseudonoise sequences thereby allowing the resolution of single acoustic paths. Receivers contained microprocessors with sophisticated signal processing algorithms for data compression and storage. A pulsed acoustic navigation system for mooring motion measurement was developed.

The program culminated in a successful field test of ocean tomography in 1981.

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IV. Acoustic Properties of the Ocean Bottom

The purpose of this program is to develop methods and techniques for determining the acoustic properties of the ocean bottom. This knowledge is necessary for the accurate modelling and prediction of the acoustic field in the water column. In particular, analytic methods and experimental procedures were devised to measure the complex (both amplitude and phase) reflection coefficient of the ocean bottom. This information is essential for the full wave equation solution for the acoustic field (or for wave equation variants such as the parabolic equation). A deep (5000 m), towed, 200 Hz acoustic source and receiver system was developed for the field program. A number of signal processing algorithms were devised for data reduction and analysis.

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V. Sonar Array Processing

The objective of this program has been to devise efficient optimal and sub-optimal procedures for processing passive sonar array data for target location and trajectory. The work was directed towards distributed arrays or interarray processing at surveillance frequencies, although the findings apply to other cases as well. The effort was entirely analytic. The primary result was the development of a decentralized technique for nearly optimal target position and velocity estimation using the maximum likelihood estimator. This method results in very little degradation in performance, but achieves considerable savings in computer processing time and costs.

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